# CONTROLLING SPEED AND DIRECTION OF STEPPER MOTOR USING XBEE MODULE

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# ABSTRACT

Nowadays the remote area is experiencing a great demand for varies field of engineering. Stepper motor, one of the most common motor widely used in controlling especially to achieve a precise measuring of a motor's rotor operation. Stepper motor is the best choice to be chosen for certain applications which requires high specification. Hence the aim for this project is to construct a stepper motor controller while enhancing its performance in terms of controlling.

The purpose of this project is to control the speed and direction of a stepper motor using Xbee module using wireless controlling method. The aim is to able to control the turn of stepper motor rotor direction clockwise or anti-clockwise and decrease or increase the speed. Instead of using in industrial application such as remote control device, valve operation or any other electrical device operation; the device also can be apply for home application such as camera monitoring.

# ABSTRAK

Pada masa kini, penggunaan alat kawalan jauh semakin luas di kebanyakan bidang kejuruteran . Motor adalah salah satu alat yang paling biasa digunakan untuk melaksanakan sesuatu kerja. Namun untuk mendapatkan pengukuran yang tepat terutamanya bagi aplikasi yang memerlukan spesifikasi yang tinggi; ‘Stepper motor” adalah pilihan yang terbaik. Maka matlamat untuk projek ini adalah untuk membina sebuah alat kawalan jauh dengan meningkatkan prestasi dari segi kawalan.

Tujuan projek ini adalah untuk membina sebuah alat kawalan yang dapat mengawal kelajuan dan arah pusingan “stepper motor” dengan menggunakan modul Xbee. Dengan itu, motor tersebut boleh dikawal dengan kaedah tanpa wayar di mana kelajuan motor boleh dipertingkatkan atau diperlahankan. Pada masa yang sama, arah putaran motor juga boleh dikawal sama ada mengikut arah jam atau sebaliknya. Peranti ini bukan saja boleh diguna dalam kawasan perindustrian malah boleh juga digunakan di tempat tinggal seperti alat kawalan kamera pemantau.

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# CHAPTER 1

# INTRODUCTION

## 1.0 Background of Study

In this modern era, electric motors are widely used in many fields of engineering and also our daily life electrical devices such as elevator. Specific types of electric motors are designed to meet particular applications. Remote and voltage input of an electric motors are specifically design to aid user easier on controlling and maintenance.

Technology grows faster and bigger, people keen to talk about efficiency, reliability and cost. Instead of using wired push button switches like old times, consumer now can control electrical device using wireless controller. Therefore, this project proposed to develop a wireless remote control for a stepper motor. This controller was developed using a module under ZigBee standard protocol called Xbee module. With a battery supported, this controller can be portable and ease the controller method within the working range.

Hence, as a future electrical engineer, this is an honor and responsibility to develop and share the technology in order to improve community life. This is how the basic idea that leads to this project of developing wireless stepper motor controller. The study and implementation of wireless stepper motor controller is believed to be helpful in controlling all other motor in the future.

## 1.1 Project Objectives

The vital objectives of this project are:

I. To develop a wireless remote controller for a stepper motor using ZigBee standard module.
II. To control the stepper motor speed; increase or decrease.
III. To control the stepper motor direction; clockwise or anti-clockwise.

## 1.2 Problems Statement

After doing some research and study, found that there are several problem generally faced in developing a controller. The problems finding are listed as below:

I. Wired controller is costly.
II. Difficult to install (complicated wiring connection).
III. More work to be done for maintenance.
IV. Instability wireless connection.
V. Fault tolerant connection.
VI. Network Configuration (complicated setting).

## 1.3 Project Scope

The project was proposed with a range of scope listed below:

I. Operating temperature: $-30^0$C ~ 70 $^0$C.
II. Operation distance: 120 meters insight; 40m indoor/urban range as in datasheet.
III. Controlling stepper motor speed and direction only.
IV. Consist of 2 Xbee module; 1 transmitter and 1 receiver.

## 1.4 Thesis Outline

The thesis begins with an introduction of the background study about the project in electric motor and the controlling method in Chapter 1. The objectives, problems statement and the project scopes are also clearly stated in this chapter.

In Chapter 2, the chapter will bring out a review of some other relevant techniques used to controller stepper motor. Several examples and ideas which had been done by others are going to discuss in this chapter together with their feedback.

The next Chapter 3 would discuss the methodology of the project which will deal with the design of a wireless controller to control stepper motor. List of component and method would be further describe in this chapter to show how thing work in itself and together to achieve the objectives.

Chapter 4 would be about the result and discussion. In this chapter, the result of the project will be discussed in detail of how the controller works in overall. The flow of the project will be clearly stated in this chapter to show how the controller works.

For the last chapter, Chapter 5 would be the conclusion of the project where the achievements of the project would be listed. Besides that, future suggestion also included for future improvement of the project.

# CHAPTER 2

# LITERATURE REVIEW

## 2.0 Introduction

Nowadays electrical motor is widely used in our daily life, no matter as small as in our laptop's hard disc till as big as in other electrical appliances such as fan, refrigerator, and washing machine and so on. Notice that, most of it is controlled by switches or button which was connected in cable on the electrical appliances; unlike television, a wireless remote control to switch on/off and channel selection. The purpose of this project is to develop a wireless remote control supported with Xbee module which able to control a stepper motor. This controller allows stepper motor to control it speed either to increase or decrease and rotation direction in terms of clockwise or anti-clockwise. Further description on each part supported with reviews and studies will be discussed below.

## 2.1 Water Quality Monitoring System

Several works had been done using ZigBee wireless network including Water Quality Monitoring System Using ZigBee Based Wireless Sensor Network [1]. Notice that, the stability of ZigBee module is meeting up to the capability to deploy a hoc or continuous monitoring purpose with numbers of sensor nodes. According to the ZigBee Alliance, ZigBee was eventually a communication standard which adopting the IEE 802.15.4 standard for reliable communication [2]. Besides that, ZigBee module also featuring low labor cost, easy to use, low power consumption and reliable data communication between sensor nodes.

## 2.2 Long Span Bridge Monitoring

Instead of using ZigBee for wireless sensor network (WSN) in water quality, ZigBee also used to monitor the condition of long span bridge [3]. After considering the disadvantages of currently used wire and cable for data communications such as high installation cost of communication and power supply for the sensors, difficult in the installation of steel pipeline for protecting the cables, sensors data distortions due to temperature changes on cables, noise affecting cables and sensor etc. ZigBee commonly used for short distance communication while CDMA (Code Division Multiple Access) infrastructure was used for long distance communication between sensors and the server system [4].

## 2.3 UPnP – ZigBee Internetworking Architecture Mirroring

Besides that, ZigBee network stability also allows to develop a multi hopping network [5]. Universal Plug-and-play (UPnP) is a good solution for integrating ZigBee networks with internet and for easily configuring ZigBee device. Although UPnP is very useful and widely used in many applications, integrating ZigBee and UPnP is a different approach of non-IP-based devices connection. This is because ZigBee network forms multi-hop connection and supported with limited nodes depending on how many module was in places. UPnP provide transparent interoperation, an UPnP-ZigBee gateway (UZG) creates/terminates virtual UPnP proxies acting as generic UPnP devices by synchronizing UZG with connected ZigBee network topology. This is enabled by injecting network monitoring functions into the ZigBee network and combining them into UZG [6].

## 2.4 Field Programmable Gate Array (FPGA)

There are many other wireless controllers that had been developed which available for stepper motor instead of ZigBee module. A reconfigurable wireless stepper motor controller based on Field Programmable Gate Array(FPGA) implementation is another great example which had been developed [7]. The idea is to design a controller using Very High Speed Integrated Circuit Hardware Description Language (VDHL) together implementing it on Spartan 3E FPGA. The controller is using Pulse-Width Modulation (PWM) technique to rotate the motor with a desired angle, speed and direction with a latent time of 10ms.

## 2.5 System on Programmable Chip (SOPC)

Another type subdivided controller of stepper motor based on system on Programmable Chip (SOPC) Technology [8]. The design method is based on the Task Flow Graph (TFG) model of the digital signal process algorithm and implemented with SOPC technology. Notice that, stepper motor system consist of 3 parts which are control section, driver section and stepper motor itself. Nios II CPU was selected for the SOPC system as the control core. This embedded system has a strong computing ability and a good networking configuration property [9]. In addition, due to the application of subdivided driving with SOPC, the stepper motor control system could meet the requirement such as some high precision positioning and accurate machining.

## 2.6 Single Microprocessor Controlling DC Stepper Motor

Stepper motor controlled by a single microprocessor was developed by sending pulse sequences to the motor winding in response to control commands [10]. Notice that the command pre-type and burned into the microprocessor. When the system initialized, the command executed by the code. The project also includes controlling the stepper motor rotate direction. The speed of the stepper motor rotation is controlled by a 16-bit timer. The timer was setup with a value that cause an underflow once every a variable second at a fix frequency [11].

### 2.7 Steering Camera by Stepper Motor towards Active Speaker

Many devices such as survey, monitoring and video recording of an event need an automatic camera steering [12]. This is highly important since the person who operates was located at another place. However the project was further suggested to uses a linear microphone array to get speech or audio signal from speakers integrating with a stepper motor based camera steering unit (CSU) [13]. These speech or audio then will compared to estimate direction of arrival (DOAs) of the speaker using multiple signal classification (MUSIC) algorithms. These estimated DOA will send signal to CSU which installed with a stepper motor for turning the camera to desire direction. Notice that, the experimental results propose that a high resolution MUSIC algorithm can be effective in steering camera especially during noisy environment too if the number of sensors in array is increased in the same time [14].

# CHAPTER 3

# METHODOLOGY

## 3.0 Introduction

In order to develop a wireless controller, several devices and software configuration are needed. The basic overall process flow of the project has been shown in Figure 3.1 as below. Generally the whole system was divided into a few main parts which include the controller, transmit medium and end device which was the execution device to move the stepper motor. However when come into solving each puzzle and put it all together to solve the matter, the whole process flow of the project had been illustrate in Figure 3.2.

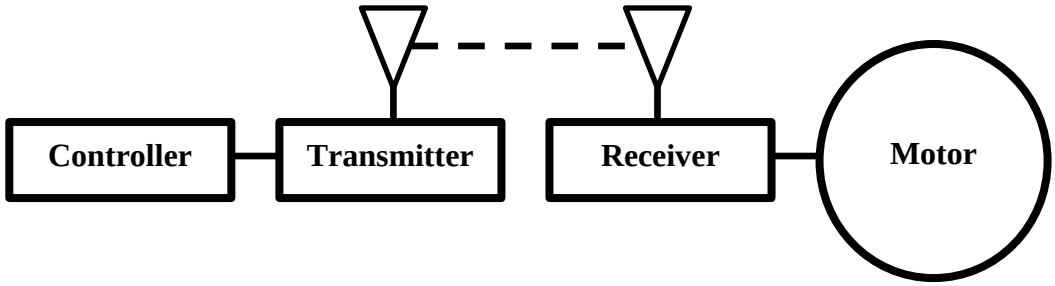


Figure 3.1: Fundamental Block Diagram

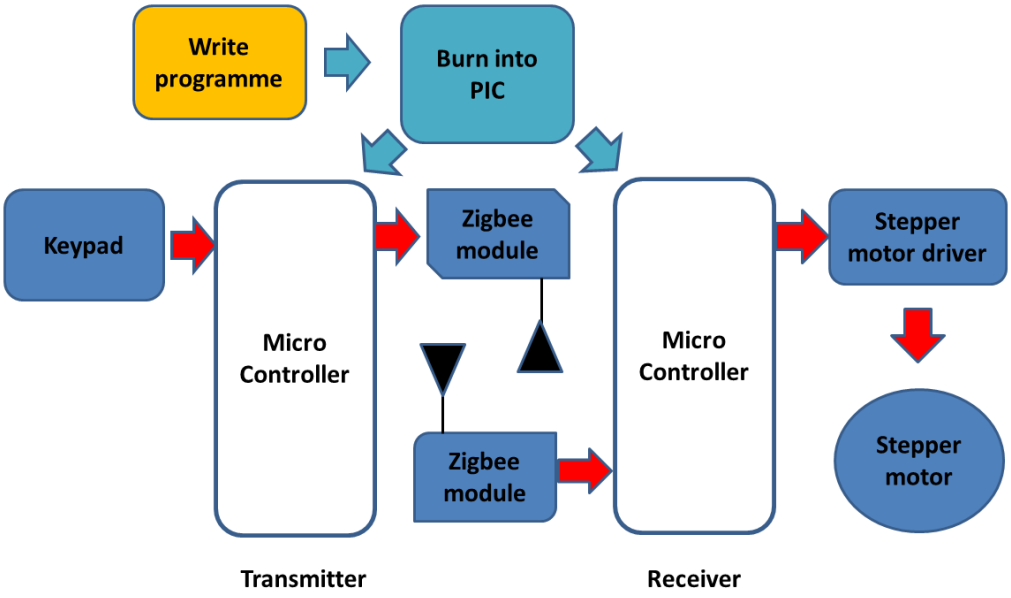


Figure 3.2: Overall Process Flow of Controlling Stepper Motor

## 3.1 ZigBee

### 3.1.1 Introduction

Millions of implementations built using ZigBee standards prove it can rely on the widest variety of smart and easy-to-use products for just about anywhere work, live or play [2]. For that reason this project are proposing to use Xbee module as the medium of transmit data, where this product was built according to ZigBee standards. Due to limited budget and stock availability, “XBEE 1mW Wire Antenna – Series 2” was selected to use in this project. Although there are other even high end types of Xbee, this product was still in the group of Series 2 which was the latest technology available in the market. Basically both Series 1 and Series 2 are the same in way of usage, just the manufacturing of the product had been improved in terms of current usage and transmitting range. Besides that, Series 2 also introduce Mesh connections

which will be further discuss in Xbee network topologies. The sample of Xbee module has been shown in Figure 3.3.

Figure 3.3: XBEE 1mW Wire Antenna – Series 2

### 3.1.2 Xbee Network Topologies

First of all, ZigBee define three different types of device which are coordinator, router and end device. The definition, comparison, and function of each device had been stated clear in Table 3.1 below.

Table 3.1: Comparison of Coordinator, Router and End device.

| **Device** | **Coordinator** | **Router** | **End device** |
|---|---|---|---|
| **Function** | Select channel and PAN ID to start a network. | Must join ZigBee PAN before it can transmit, receive or route data | Must join ZigBee PAN before it can transmit, receive or route data |
| **Allow router and end device to join** | Yes | Yes, only after joining. | No |
| **Assisting in routing Data** | Yes | Yes, only after joining. | No |
| **Sleep** | Not allow | Not allow | Allow |

From the table, notice that Coordinator and Router plays important role in buffering radio frequency data packets for end device which was connected into the network. An example of such network has been illustrated shown below in Figure 3.4.

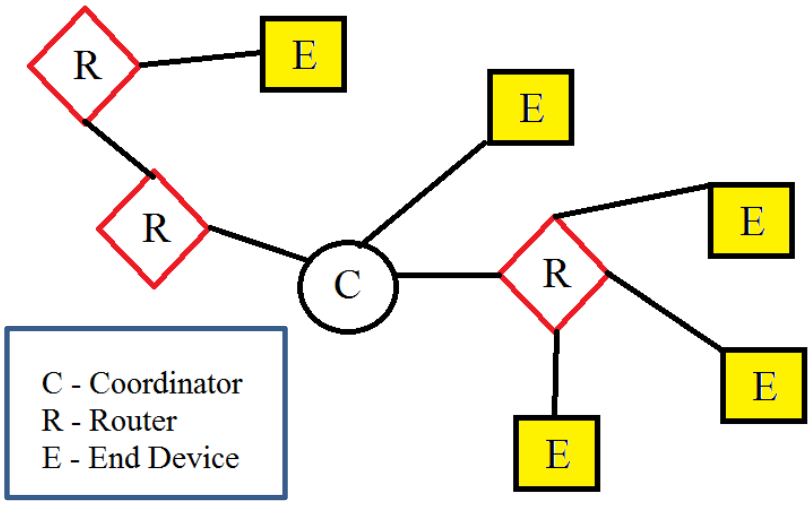


Figure 3.4: ZigBee Network Connection Example.

The network is called personal area networks, PANs and each network is defined with a unique PAN identifier called PAN ID. A coordinator is needed to configure a PAN ID to allow other devices to join. Devices can be manually set or discover nearby networks themselves and select to join.

Generally ZigBee network was set up base on three types of topology which is Point-to-point, Many-to-one and the latest released Mesh routing. Many-to-one routing is use when there are many devices sending data to the central collector. Notice that if the device itself had to discover a route before it can send data, the network could flood. In order to overcome this problem, instead of each device searching its own route, a single many-to-one route was set to send data from data collector while establishing a reverse route on all devices. The network has been illustrated in Figure 3.5. In that case, when a device send data to data collector, it will find a many-to-one route and transmit the data without searching a new route instead.

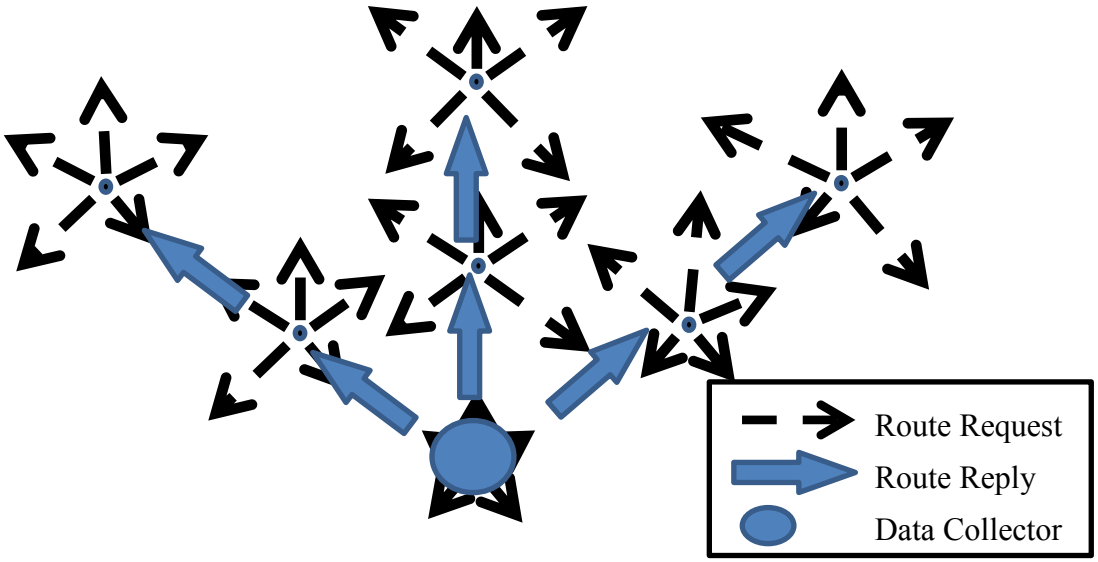


Figure 3.5: Many-to-One Network Illustrates.

Unlike many-to-one, Mesh routing is to build a route between source device and destination where the data was allowed to travel multiple nodes or also known as hops. Router and Coordinator took parts on building route between source and destination device using a process call route discovery. This process would begin from sending route request, compare the options and select the most ideal route path to send the data to destination. Figure 3.6 and Figure 3.7 shows an example on how the process works.

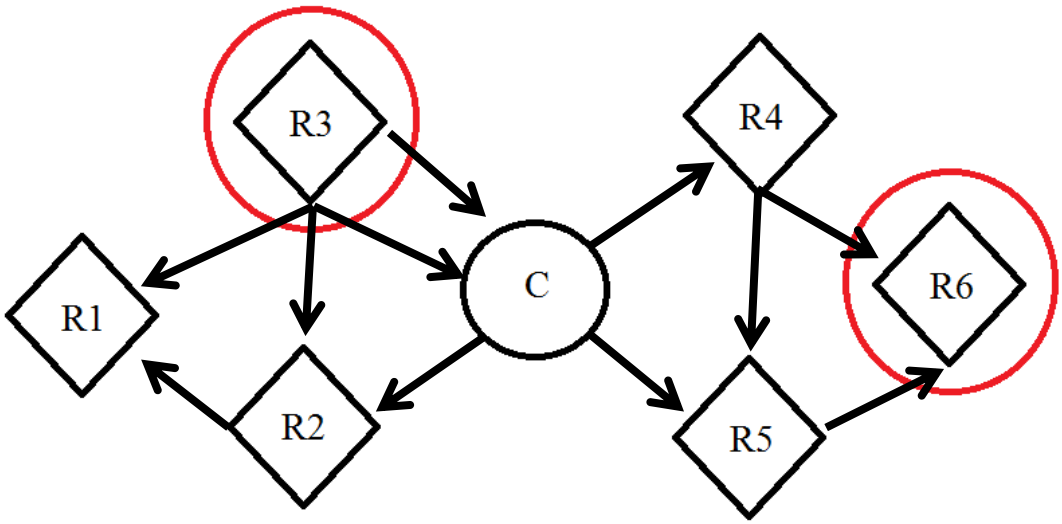


Figure 3.6: Sample Route Request for Data Sending from R3 to R6

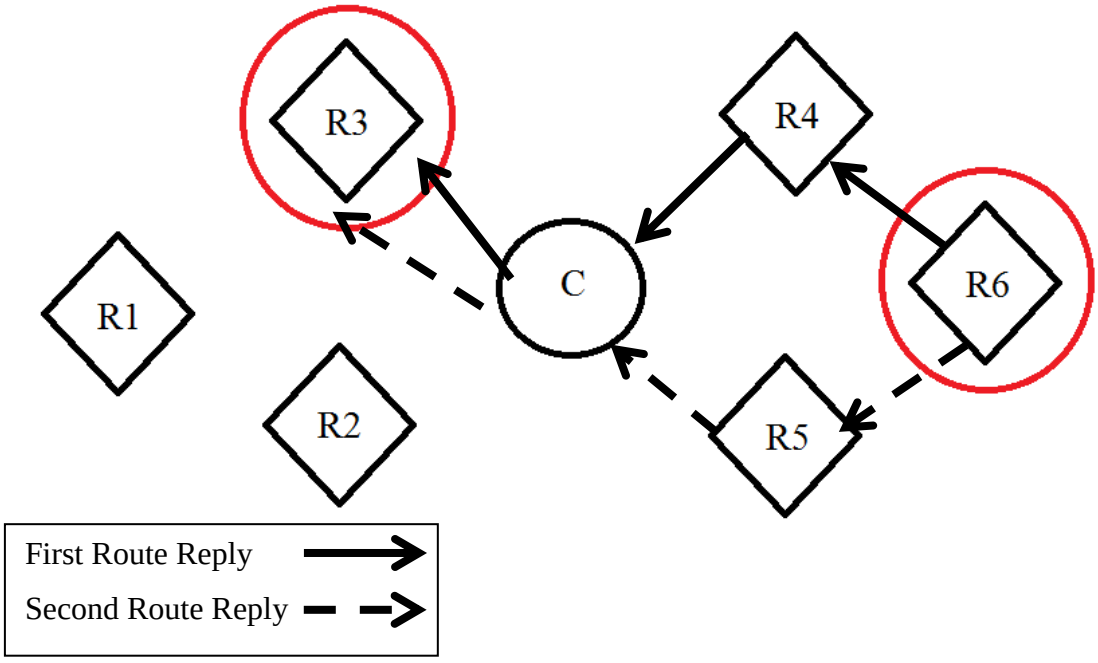


Figure 3.7: Route Reply from R6 to R3

Figure 3.6 shows that, R3 was sending multiple routes request to other router in order to search the suitable path. When the destination node receives a route request, it will automatically compare the path against other request. If it was better than any other, the destination node will transmit a route reply to the originate route request node. Instantly after receiving the reply, source node will packet up the data and send to destination shown in Figure 3.7.

Last is Point-to-point routing, this is the simplest routing communication where it was only consist of two points. Only one coordinator and one router are needed to establish this connection. After set the same PAN ID for both nodes, it will automatically connect to each other once both nodes were in transmitting range.

The method that going to be use in this project is Point-to-point routing, because it was only consist of two point; controller and stepper motor. The objective is to send data from the controller to another node which connected to the stepper motor driver and drive the stepper motor on command. The communication can be easily set up by using X-CTU software which will be further discuss in following subchapter.

Notice that all route discovery process is based on AODV (Ad-hoc On-demand Distance Vector routing) protocol. The process is accomplished using tables of each node that store the next hop for destination nodes. If next hop is not known route discovery with take place in order to find another path. Route discovery usually take place more often in a large network with communication between many different available nodes [2].

## 3.2 Controller Design

The controller method is simple and efficient where simple push button was selected for the design. In order to determine the numbers of button needed, first it must come to understand the objective of the project. Notice that main objective of the project is to control the speed (increase/decrease) and direction (forward/reverse) of the stepper motor. Additional an ON/OFF switch also include for starting or stopping the stepper motor. A reset button also added to reset both PIC18F4550 and Xbee module. In conclusion, 7 buttons was decided in the design for controller, the number and function of each button had been clearly stated in Table 3.2 below. The button will be connected to PIC18F4550 as an analog input, wiring connect is shown in Figure 3.8.

Table 3.2: List of Button and Function.

| **Button number** | **Button Title** | **Function** |
|---|---|---|
| **Button 1** | On button | To enable stepper motor to start |
| **Button 2** | Off button | To disable stepper motor to stop. |
| **Button 3** | Forward button | To switch stepper motor rotation to forward direction. |

| | | |
|---|---|---|
| **Button 4** | Reverse button | To switch stepper motor rotation to reverse direction. |
| **Button 5** | Speed increase button | To increase stepper motor rotation speed. |
| **Button 6** | Speed decrease button | To increase stepper motor rotation speed. |
| **Button 7** | Reset button | Reset button – to reset PIC18F4550 and Xbee |

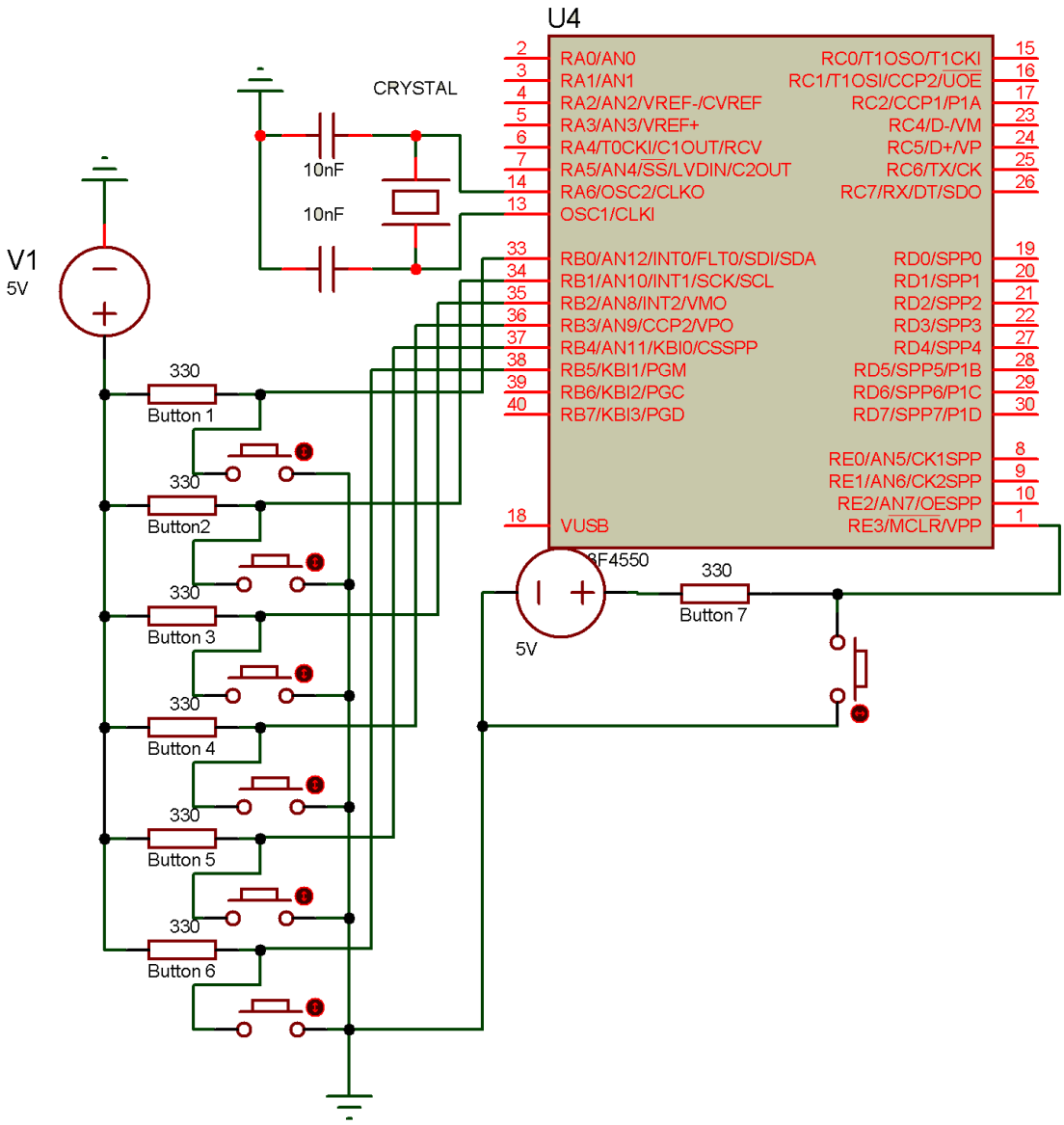


Figure 3.8: Button Wiring Connection.

Every button will be connected to PIC18F4550 as an analog input to send out order to execute each particular function. Wiring connection will be further discussed in PIC18F4550 subchapter. Speed availability has been manually set. 4 different speeds had been set in PIC18F4550 by using TIMER555 which will further discuss below. Controller method only discuss the way how analog input was send to the system to execute designate command, further control of stepper motor would be discuss in next subchapter in Stepper motor driver.

## 3.3 Stepper Motor

### 3.3.1 Introduction

Stepper motor defines as a brushless DC electric motor that divides a full rotation into a number of equal steps. The motor consist of a permanent magnet rotating shaft (rotor) and electromagnets on the stationary part around the motor (stator). When each particular stator was electrified, rotor will divert their direction to it. The rotation of stepper motor was illustrated as in Figure 3.9 below.